Defining: Constructing precise ideas

Schedule	20 minutes: initial discussion and student writing 30 - 40 minutes: small group work on constructing a definition 20 minutes: whole class conversation (optional) 30 minutes: small group work
Materials	a pencil a block or book one “Descriptions” worksheet per student one “Book” worksheet per group, paper or via Google Doc one (half-page) exit slip per student a small whiteboard per group
Set-up	Students will work individually and then in groups of 3 Projector Optional: computer for each group (to use Google Doc instead of worksheets)

Background:
In many science courses students are taught definitions (e.g., *velocity is a vector quantity that indicates the rate of change in position*), and they interpret and employ these in developing arguments or solving problems. These definitions are presented as incontrovertible, if not altogether obvious, as if they are the launching point of inquiry rather than a hard-fought, hard-won product of scientific inquiry. And while much scientific research does proceed from well-defined terms (and knowing how to read, interpret, and use those terms is critical), this is hardly true for all research. Defining terms (e.g., species, acceleration, life, acid, planet, particle, etc.) is a challenging and iterative process that underlies a great deal of scientific inquiry. As Bazerman (1988) notes “In Bacon’s day the word acid meant only sour-tasting; then it came to mean a sour-tasting substance; then, a substance which reddens litmus; then, a compound that dissociates in aqueous solution to produce hydrogen ions; then, a compound or ion that can give protons to other substances; and most recently, a molecule or ion that can combine with another by forming a covalent bond with two electrons of the other... The tasting and taster vanish as the structure emerges” (p. 164). That is, as progress was made on understanding acids, the definition changed not only in its precision but also in the nature of the definition, shifting from a subjective experience to an operational definition to a theoretical account. For Galileo, determining whether he would define acceleration as change in speed per unit time or change in speed per unit distance was of considerable importance; the most useful choice is not at all obvious prima facie.

Selecting a term to define
Below we describe a workshop we have run with a range of students as a way of making defining an explicit activity. For this, we ask students to define a familiar, somewhat scientific term that has a range of possible interpretations and represents a pattern underlying multiple

phenomena: *threshold*. This workshop stems from Angela (Angie) Little's dissertation on crafting and using definitions (Little, 2013).

Getting started
To begin, students each have a worksheet ("descriptions" worksheet) and a shared whiteboard for their group.

Begin by saying something like: *"First, I'm going to show you some videos and you'll watch me do two things. I'd like you to write a sentence or two describing what you observe happening for each of these four cases."*

[Instructor shows four examples, waiting a minute between examples to allow participants to write down their sentences. Examples are: pushing a block slowly off the edge of a table until it falls, taking a pencil with two hands and bending it which eventually snaps it in half, a tea kettle being heated on a stove until it whistles, and a balloon being blown until it pops.]

- https://www.youtube.com/watch?v=OGx-_azevDM
- https://www.youtube.com/watch?v=DNBS6Vj4GLQ&feature=autoplay&list=

Instructor: *On your worksheet, there's a question that asks whether you've noticed a pattern in this set of four examples. If you have, take a moment to write it down.*

[Students write. Examples of past student responses include: "tipping point," "anticipation, and "people do stuff."]

Instructor: *So I've shown you four situations that I think are pretty good representatives of the idea of threshold. What I'd like you to do before we talk together is take a couple of minutes to write down, just brainstorm anything, any other examples that come to mind that you think 'yeah, that could probably be called threshold.' Go quickly and toss out ideas; we'll come back together for sorting them through.*

[Students write down their brainstormed examples. Examples have included "an earthquake," "getting tall enough to ride a ride at the fair," "chopping down a tree," "a pain threshold."]

Instructor: *There's clearly many, perhaps even better, examples than what I've just shown you, and the idea is that we'd really map out the idea of threshold. The idea is that we're going to write a book to help people a little younger than us identify threshold out in the world. You can imagine a book on birds has some central definition: a bird has a beak, wings, is warm-blooded, etc., and then there might be some other chapters on more atypical birds like large flightless birds (emus, ostriches) or tropical birds (particularly colorful birds like parrots). That's the idea here – you'll first craft a central definition and if you have time, you'll work on the chapters. The definition can take awhile so don't worry if that's all that you get to. So that's your task. I'll play a instructor role -- just making sure you're staying on track, suggesting a few possibilities here or there, asking a few questions, etc. Every time I talk with people about these ideas I learn something new, so I'm looking forward to the conversation.*

First, though, I want us to get a good list of thresholds. I'll ask you to get in your group of three and share the examples you came up with. From those, choose one example that you think is a very clear example of a threshold, and one that is a "fringe" example - something you think is a threshold, but maybe is not obvious. Write those on your whiteboard and we'll share our ideas in about 3 minutes.

As you walk around to each group, make sure that the examples they put on the board are ones they all agree count as “threshold” events.

Instructor: And then I’ll ask you to debate with each other -- are all of these, are all the ones I showed, good examples of threshold? How should we really define it?

Students go around sharing one example out at a time. If students seem unsure whether or not social examples should be included, instructor tells them: “A group of graduate students who did a workshop like this also came up with the examples of poking someone until they punch you.” This move either causes participants to explicitly ask, “Should we consider social examples, too?” or to start sharing social examples. Answer: “So sure – kids are seeing all kinds of things out in the world. I think those can count to help kids identify thresholds out in the world.”

Instructor hands out two pieces of paper. One has “Definition” written across the top. The other has “Chapter Ideas” written across the top. There is some scratch paper around students can write on also (both a large piece of paper the covers most of the top of the table and a few smaller 8x11 sheets).

Instructor: The idea is that as a group you’ll decide what your definition and chapter ideas are and you’ll write them on these two pieces of paper here. You’re free to use scratch paper in your work as you proceed.

Participants begin work on crafting definition. Once the task is set up, you may not need to interact with a group for about 20 minutes. – Take a temperature around 10 minutes to see progress. Groups should have a first-draft of definition by this point, but if they are stuck on how to word the definition, you might note: “*Some groups work on defining it in their own way before figuring out how to word it for kids*.” If a small group seems done prematurely, you might ask, “*what have you been up to?*” – they often share something that they have been debating or working on how to phrase. If simply asking this does not re-ignite a conversation, ask: “*Can I give you a couple different examples to think about and see if they fit your definition?*” Here you can give examples that other groups are considering, trying to categorize, or don’t quite know whether they should count as instances of threshold.

Whole class conversation

The point of a whole class conversation about thresholds is to engage students in a more nuanced discussion of the definition - as a way of considering the kinds of contentious debates that underlie many scientific and academic categories. To do this, we introduce some debatable “thresholds” and consider: do you believe these should count as “threshold” events? what does your definition say? what do others’ definitions say?

As groups feel somewhat settled on their definition, ask the groups to write their definition on the whiteboard. As they do that, write on the board at the front of the room the following examples:

- Milk going bad in the fridge
- Getting old
- A light turning from red to green

To begin, ask for an explanation (“can anyone briefly describe what’s happening when milk goes bad in the fridge?”) or simply give a brief explanation (“so milk has all kinds of microorganisms in it, and they usually cannot reproduce and grow quickly in the refrigerator. But over time, eventually they do grow and reproduce enough so that you can taste that the milk has gone bad.”).

Then have students decide at their table whether or not each of these (a) is an example of threshold and (b) if their definition is consistent with their response to part (a). Once their table is done, begin discussion by, perhaps, asking for a show of hands, “So I’m wondering how many of you think that milk going bad is a threshold. Raise hands?”

In our classes (so far) there has always been disagreement on this question. Some, for example, may decide that there is no one “moment” at which you could say milk has gone sour, and that this means it does not qualify as having reached a “threshold.” Others believe that a “moment” for a threshold can be a more gray area, and that the transition does not need to be abrupt. Others argue that if “gone bad” is a certain number of parts-per-million of bacteria in the milk, then there is a well-defined transition or threshold. As you hear these, you might discuss whether or not they are arguing over the definition of threshold, a sub-definition (for example, if most definitions include the idea that there is an “abrupt” or “sudden” change, you may note that what they disagree on is that term), or on the definition of “gone bad.”

In some classes, for example, we have generated subcategories of ambiguous/subjective thresholds, and then later realized that these two categories were not the same: a threshold can be subjective without being ambiguous (when a steak is done).

As new ideas are considered and definitions are refined, consider the other test cases (getting old and red/green).

Debrief
After a discussion regarding how students conceptualize and define threshold, we discuss the role of defining in science. Recent examples include re-defining planet, such that Pluto is no longer a planet. Other examples can be found here:
http://www.nature.com/news/2008/081022/pdf/4551023a.pdf

Variations
In a class where students were investigating lenses and cameras, we asked them to generate a range of examples of “blurriness.”

In conversations and groups thinking about definitions not specifically tied to science, the term “sandwich” has been productive.

Resources:
This material draws from our work published in Atkins Elliott, Leslie, Jaxon, Kim & Salter, Irene. *Composing Science: A Faciliator’s Guide to Writing in the Science Classroom*. Teachers College Press & the National Writing Project, 2016.